The Impact of Patent Pools on Further Innovation

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Any comments and suggestions are welcome and appreciated!

Abstract

Studies of patent pools have been focused on their initial formation and their influences on product markets through pricing strategies. We took the first step in building a theoretical model to understand patent pools' influence on further innovation in the industry. We adopt an *ex post* perspective and studies pool members and non-pool members' research strategies on either investing on incremental technology or inventing a substitute technology after a pool has been formed among the complementary essential patent holders for a technology. We also model the dynamic change of the pool with the incremental patents available in the technology market. Our study shows that profit distribution rules among pool members and the preference heterogeneity in the product market play crucial roles in firms decision when choosing further innovation strategies and participating in the patent pools.

Key Words: Patent Pools, intellectual property, incremental innovation, substitute technology

Paper Outline:

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  II.2. Inventing an inferior substitute technology
III. A benchmark model without patent pools
IV. Extension and revision of the model
  – A Bargaining model is build for profit sharing rule
  – Influences of the antitrust policy regarding patent pools formation
V. Concluding Discussion

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I. Introduction

Patent pools were introduced to serve as a remedy for patent thicket problem and excessive litigation. The intended consequence is to lower the transaction costs and improve the efficiency in the licensing and production process. Because patent pools could be used to gain and abuse market power among substitutable patents, antitrust issue has always been a concern in this subject, as studied by Shapiro [2001] and Gilber [2002]. As antitrust policy can boil down to loss or gain in efficiency, many studies about patent pools studied the efficiency implications of patent pools, including Kim [2004], Lerner & Tirole [2004], Gilbert [2009], Jeitschko & Zhang [2011], among others. Gilbert [2010] studied what policies can be used to promote efficient patent pools. In reality, gaining efficiency is not the only motivation for patent holders to form a pool. Choi [2010] showed that firms can form a patent pool as an attempt to settle disputes in regard to conflicting infringement claims and the validity of patents. To summarize, the majority of the existing research have been focused on the product market.

How has patent pooling influenced further innovations in technology market? In this paper, the incentives to further innovate for both patent pool members and non-members will be examined and the innovation quality revealed in final products with and without patent pools will be compared. Given the preference heterogeneity in the product market, the outcome of the game will be largely determined by two factors: one is the profit sharing rule set by the patent pools and whether the pool can commit or not, the other is the antitrust framework that might put restriction on the inclusion of the inferior substitute technology in the patent pool.

Baron and Delcamp [2010] is an empirical study that inspired our current theoretical research. Their article explores the impact of contemporary patent pools on firm patenting strategies. They prove that firms that are already members of a pool are able to include narrower, more incremental and less significant patents then outsiders.

Lampe and Moser [2009] is another interesting research on how patent pools encouraged innovation using data from the first patent pool in U.S. history, the Sewing Machine Combination (1856-1877). Their data confirm that member firms patent more in the years leading up to the pool; they do however, patent less as soon as the pool is established. Because the sewing machine pool discouraged innovation by increasing the threat of litigation for outside firms, innovation slowed for the duration of the pool and only increased again after the pool had expired. Their data also indicate that outside firms shifted towards inferior technologies.

Joshi and Nerkar [2011] empirically showed that patent pools reduce the innovation quantity and quality by both the licensors and the licensees, using the data from the optical disc industry.

Besides those empirical studies, Dequiedt and Versaevel [2006] is a theoretical research on how the possible patent pools formation provide the dynamic incentives to R&D. Because participation in the creation of a pool acts as a bonus reward on R&D activity, they show that a firm's investment pattern is upward sloping overtime before pool formation. Thus, a pool formation mechanism based on a proposal by the industry or by the competition authority may induce overinvestment in early innovations and result in a pool size that is suboptimal from an ex ante viewpoint.

Different from Dequiedt and Versaevel [2006], our model adopts an ex post perspective and studies how the pool members or outsider firms may choose research investment and patenting strategies differently after a pool is already formed and thus have an impact on the incremental innovation in the industry. We will also study the welfare implications and policy implications to technology policy makers or competition authorities.

The model we built is closely related to two papers. Cheng & Nahm [2007] studies how adding a non-essential complementary product into a market will influence firms' pricing strategies. Shi [2009] studies bundling and licensing of genes in agricultural biotechnology. More specifically, it analyzes the strategic incentive for gene holders to vertically integrate with see companies, and with herbicide/insecticide oligopolies. These papers are relevant to our study because in the last stage of the game we will model an essential technology with an incremental innovation adding to the technology market. But in our model there will be a patent pool and incremental technology is a choice variable, so the settings will be different from their papers.

More discussion will be added later.

The paper will proceed as follows. In section II, we introduce a four stage game in which the patent pool chooses between equal profit sharing rule and marginal contribution rule after the innovation is conducted. In section III, we build the benchmark model where no patent pool exists and then compare the results with section II. In section IV, we extend the model by revising the profit sharing rules and the antitrust policy framework and compare the new outcomes with previous ones. In section V, we further discuss the outcomes and make concluding remarks.

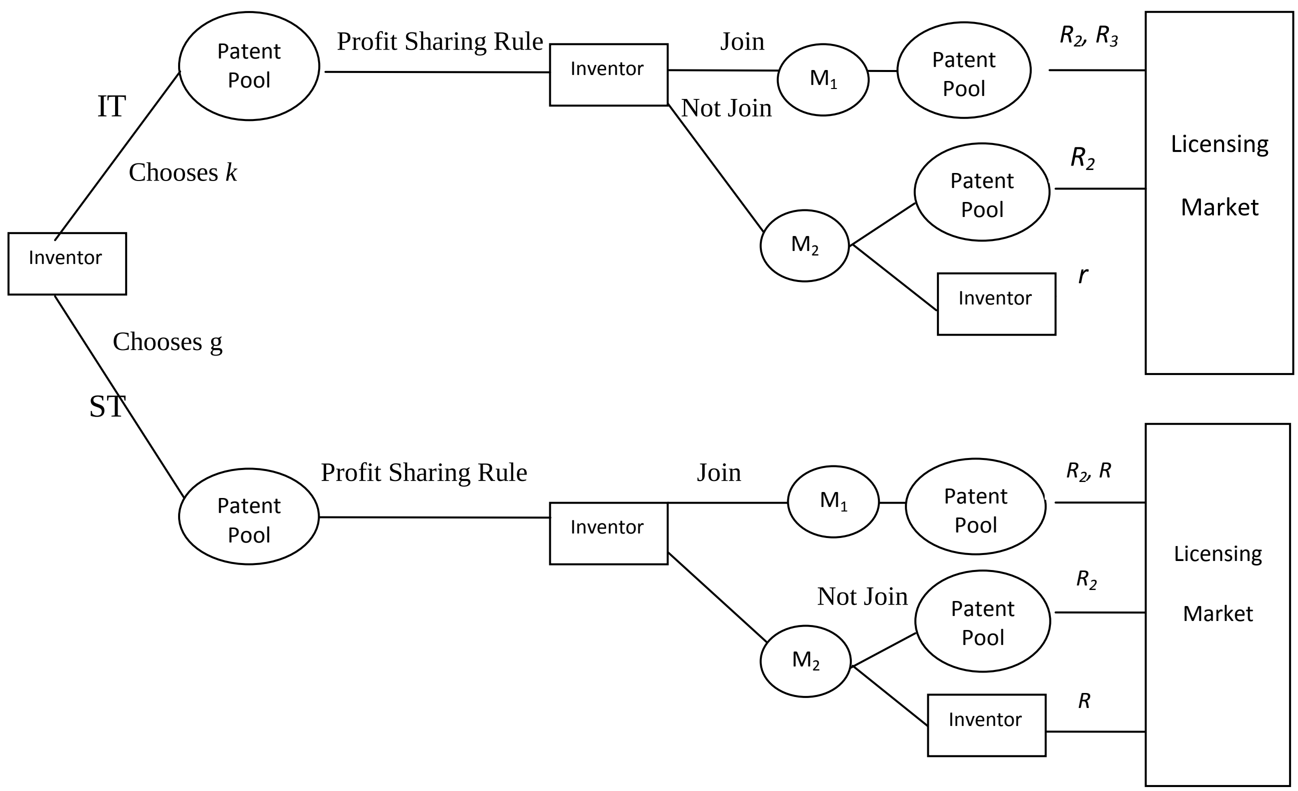
II. The base model – With a patent pool

In this section, we consider the scenario where a patent pool has been formed between research firms A and B in the industry. Firm A owns essential technology, T_a and firm B owns essential technology T_b. For the simplicity purpose of the analysis in this section, we assume that T_a and T_b are symmetrically essential in the production of final product. One of the pool members or an outsider firm C then will invest *k* in either an incremental technology IT, which is useless by itself but can improve the final product's performance or quality by adding traits or functions, or a substitute technology ST. We will use technology name as patent name throughout the paper. Also, we will not model the potential technology race between the pool member and the outsider firm in this paper, although it is worth modeling in a separate paper.

Following the successful patent application of the new technology, IT or ST, the original patent pool could include it into the patent package and license all three patents to the downstream firms, if the interests are mutual. The downstream firms have the choice whether to produce the basic product by licensing only Ta and T_b or using all three technologies and produce the advanced product.

The game has four stages: innovation, patent pool announcing profit sharing rules, patent pool participation decision and licensing in the technology market. In the first stage, the innovator company chooses between investing in IT or ST, decides the investment level and incurs a cost correspondingly. In the second stage, the existing patent pool chooses a profit sharing rule with new patent owner if they decide to join the pool. In the third stage, patent T owner decides to join the pool or stay out. In the last stage, all decision units remained choose royalty rates for their respective licenses in the technology market. More specifically, if patent IT joins the pool in the second stage, M_1 market structure arises, then only the pool needs to make royalty decision for the package. If new patent stays out, then M_2 market structure arises and the original pool and the patent owner make choices simultaneously. Patent pool has the option to only offer the basic technology package of Ta and T_b. After observing the royalty rates, downstream production firms make license purchase decision.

The game tree can be illustrated as below.



Downstream technology licensees are heterogeneous in valuing quality, due to the differences in target markets, production technology, specialty assets, management expertise, etc. We use θ to describe the type of the buyers, and θ is uniformly distributed over [0, 1]. The technology licensees are risk neutral and they know their types before purchasing.

II.1. Incremental technology strategy

In this case, there are two possible products in the final market: lower quality product, *L*, with a performance level q and higher quality product, *H*, with a performance level $q + k$. q is exogenous and k is a choice variable to the incremental innovator. We use Q as a quality level index, $Q = q, q + k$.

Assumptions:

1. For simplicity, we assume marginal cost to any patent holder is zero.
2. The licensees who plan to produce H product will face two types of technology market structures, M_1 and M_2. If a patent pool including T_a, T_b, and IT has been formed, we call it structure M_1, i.e. a complete patent pool. If the incremental patent does not become the member of the pool, we call it structure M_2, an incomplete patent pool. Under M_1, the pool set royalty R_3 for three patents and R_2 for T_a and T_b. Under M_2, the pool set royalty R_2 for two basic patents and the incremental patent owner sets royalty r for the new patent. Assume that the patent pool cannot discriminate between licensees who produced H and those who produce L under M_2.
3. There exists a transaction cost f for H producers in M_2 market. There is no fix cost for L producers and for H producers in M_1 market.
4. A licensee of type θ has a reservation value $V(\theta) = v + \theta Q - f_{ij}$, $i = M_1, M_2$; $j = L, H$, and $Q = q, q + k$. Assuming $f_{iL} = f_{M_1H} = 0$; $f_{M_2H} = f$.
5. Royalty for a patent package including T_a, T_b, and IT is denoted as R_3. Royalty for the basic patent pool with T_a and T_b is denoted as R_2 and royalty for IT only is denoted as r.

Given the above assumption, we can write down the surplus of licensee of type θ as below:

$$V(\theta, L) = v + q\theta - R_2$$

$$V(\theta, H, M_1) = v + (q + k)\theta - R_3$$

$$V(\theta, H, M_2) = v + (q + k)\theta - R_2 - r - f$$

Solve for the condition of choosing L or H, we have the following results:

Under both M_1 and M_2: Licensee of type θ chooses not to produce if $\theta < \frac{R_2 - v}{q}$

Under M_1, licensee of type θ chooses to produce L if $\frac{R_2 - v}{q} < \theta < \frac{R_3 - R_2}{k}$,

and H if $\theta > \frac{R_3 - R_2}{k}$

Under M_2, licensee of type θ chooses to produce L If $\frac{R_2 - v}{q} < \theta < \frac{r + f}{k}$,

and H if $\theta > \frac{r + f}{k}$

Solve the game by using backward induction. On the license market:

Under M_1 structure, the patent pool includes three patents, T_a, T_b and IT. The pool's maximization problem is:

$$\max_{R_3, R_2} R_3\left(1 - \frac{R_3 - R_2}{k}\right) + R_2(\frac{R_3 - R_2}{k} - \frac{R_2 - v}{q})$$

Solutions: $R_3 \to \frac{1}{2}(k + q + v), R_2 \to \frac{q+v}{2}$

Pool's total profit: $\frac{kq+(q+v)^2}{4q}$

Under M_2 structure, the patent pool only includes patents T_a and T_b.

The pool: $\max_{R_2} R_2(1 - \frac{R_2-v}{q})$

IT owner: $\max_r r(1 - \frac{r+f}{k})$

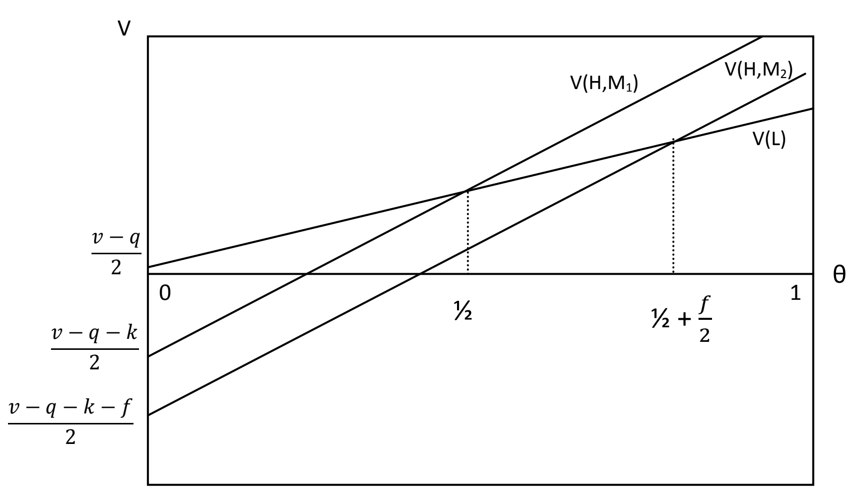
Solutions: $R_2 \to \frac{q+v}{2}, r \to \frac{k-f}{2}$

Pool's profit: $\frac{(q+v)^2}{4q}$

IT owner earns: $\frac{(f-k)^2}{4k}$

Plug R_2, R_3 and r into the expression for θ, we can find the threshold of the market share for H and L products in the final market. Depending on the relationship between v and q, the market share can be illustrated as below:

Lemma 1 (scenario 1): $v \geq q$ For $v \geq q$, all licensees will enter the licensing market and produce either L or H products. More specifically, under M_1 structure, half of the licensees with $0 < \theta < \frac{1}{2}$ will produce L products and the other half of the licensees with $\frac{1}{2} \leq \theta \leq 1$ choose to produce H



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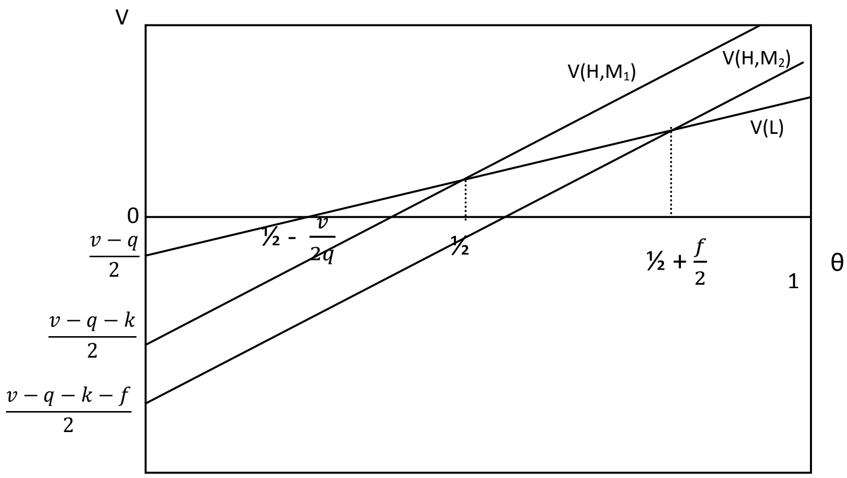


Lemma 2 (Scenario 2): For v < q, licensees with $0 < \theta < \frac{1}{2} - \frac{v}{2q}$ choose not to license. As for whether the licensees choose to produce H or L, it depends on the pooling structure of the technology market.

Under M_1 structure, licensees with $\frac{1}{2} - \frac{v}{2q} < \theta < \frac{1}{2}$ choose to produce L product and licensees with $\frac{1}{2} \leq \theta \leq 1$ choose to produce H product.

Under M_2 structure, licensees with $\frac{1}{2} - \frac{v}{2q} < \theta < \frac{1}{2} + \frac{f}{2}$ choose to produce L product and licensees with $\frac{1}{2} + \frac{f}{2} \leq \theta \leq 1$ choose to produce H product.

In both scenarios, H market does not exist when f > 1.

II. 1.1 Licensing market results and payoffs of the last stage game

In this section, profits are split between pool members under certain profit sharing rules or through bargaining process.

Case 1: Equal split profit sharing rule: that is, the profit from a three-patent based license will be equally split among patents.

If pool member A also is the innovator:

Under M1 structure, firm A can earns 2/3 of the profit from H market and ½ profit from L market and firm B earns 1/3 of the profit from H market and ½ profit from L market Under M_2 structure: firm A and B split the pool profit and firm A also earns the profit from IT. The results are shown as below.

If an outside firm C is the innovator:

In this case, A and B always split the profit earned in the pool from licensing to both the H and L markets, and C will earn the profit from licensing to the H market.

Payoffs are summarized and listed in the following table:

	A owns both T_a and IT	C owns IT
M_1^{ES}	$\pi_A = \frac{4kq+4q^2+7qv+3v^2}{24q}$ $\pi_B = \frac{2kq+2q^2+5qv+3v^2}{24q}$	$\pi_A = \frac{2kq+2q^2+5qv+3v^2}{24q}$ $\pi_B = \frac{2kq+2q^2+5qv+3v^2}{24q}$ $\pi_C = \frac{1}{12}(k+q+v)$
M_2	$\pi_A = \frac{(q+v)^2}{8q} + \frac{(f-k)^2}{4k}$ $\pi_B = \frac{(q+v)^2}{8q}$	$\pi_A = \frac{(q+v)^2}{8q}$ $\pi_B = \frac{(q+v)^2}{8q}$ $\pi_C = \frac{(f-k)^2}{4k}$

<u>Case 2</u>: Profit for IT owner is determined by the marginal contribution of the IT patent to the pool under M_1 structure

In this case, what the IT patent owner can earn is the difference between patent pool's total profit with and without IT patent, no matter whether A or C owns the IT patent.

	A owns both T_a and IT	C owns IT
M_1^{MC}	$\pi_A = \frac{2kq+(q+v)^2}{8q}$ $\pi_B = \frac{(q+v)^2}{8q}$	$\pi_A = \frac{(q+v)^2}{8q}$ $\pi_B = \frac{(q+v)^2}{8q}$ $\pi_C = \frac{k}{4}$

II.1.2. Pooling decision

A new patent pool with IT patent will be formed if and only if both the IT patent owner and the existing pool members can maintain or improve their profit level with the new pool.

Results:

Case 1: Equal split profit sharing rule,

If C owns the patent IT:

C joins the pool if $\frac{1}{12}(k+q+v) > \frac{(f-k)^2}{4k}$. Solve for *k*,

$$\frac{1}{4}\left(6f+q+v-\sqrt{-24f^2+(6f+q+v)^2}\right) < k < \frac{1}{4}\left(6f+q+v+\sqrt{-24f^2+(6f+q+v)^2}\right)$$

and AB accept C if $k > \frac{q+v}{2}$.

As $\frac{1}{4}\left(6f+q+v-\sqrt{-24f^2+(6f+q+v)^2}\right) < \frac{(q+v)}{2}$, we have the following conclusion.

Lemma 3: If C owns patent IT under equal split profit sharing rule, then a complete patent pool with technology T_a, T_b and IT will be formed if and only if $\frac{(q+v)}{2} < k < \frac{1}{4}\left(6f+q+v+\sqrt{-24f^2+(6f+q+v)^2}\right)$.

If A owns the patent IT:

A will add IT patent to AB pool if

$$\frac{1}{4}\left(12f+q+v-\sqrt{-48f^2+(12f+q+v)^2}\right) < k < \frac{1}{4}\left(12f+q+v+\sqrt{-48f^2+(12f+q+v)^2}\right)$$

On the other hand, B will let IT join the pool if $k > \frac{(q+v)}{2}$. Thus we have the following conclusion:

Lemma 4: If A owns patent IT under equal split profit sharing rule, then a complete patent pool with technology T_a, T_b and IT will be formed if and only $\frac{(q+v)}{2} < k < \frac{1}{4}\left(12f+q+v+\sqrt{-48f^2+(12f+q+v)^2}\right)$.

So, there is a minimum quality of IT so that a complete patent pool will be formed.

Note 1:

$\frac{1}{4}\left(12f+q+v+\sqrt{-48f^2+(12f+q+v)^2}\right) > \frac{1}{4}\left(6f+q+v+\sqrt{-24f^2+(6f+q+v)^2}\right)$, thus we are more likely to observe a complete patent pool if a member of the existing pool invents the incremental technology.

Note 2: If A owns the IT patent and AB pool decides about whether accepting IT as a whole organization, then AB pool is indifferent between adding IT and not.

Case 2: Marginal contribution profit sharing rule

If C owns patent IT, then C joins the AB pool if $\frac{k}{4} > \frac{(f-k)^2}{4k}$, i.e. if $k > \frac{f}{2}$. And AB pool is indifferent between adding IT or not.

If A owns patent IT, then B will be indifferent about adding IT and A will add IT to form the complete pool if $\frac{kq+(q+v)^2}{4q} > \frac{(q+v)^2}{4q} + \frac{(f-k)^2}{4k}$, i.e. if $k > \frac{f}{2}$.

Lemma 5: Under marginal contribution profit sharing rule, a complete patent will be formed if $k > \frac{f}{2}$ regardless of the owner of the IT patent.

Note: Under marginal contribution profit sharing rule,, q and v will be unimportant.

Lemma 6: If a complete pool is to be formed and if C owns the patent IT, then C prefers marginal contribution profit sharing rule.

Proof: $\frac{k}{4} > \frac{k+q+v}{12}$ if $> \frac{(q+v)}{2}$.

If $k < \frac{(q+v)}{2}$, then a complete pool is not to be formed under equal profit sharing rule.

II.1.3 Investment decision

Assume the innovator of IT incurs a quadratic cost of added quality level *k*. The objective functions of the innovator under different scenarios and the choice of *k* are listed below.

Payoffs are summarized and listed in the following table:

	A invests in IT	C invests in IT
M_1^{ES}	$\max_k(\frac{4kq+4q^2+7qv+3v^2}{24q}-\frac{k^2}{2})$ $k=\frac{1}{6}$ $\pi^A=\frac{q+12q^2+21qv+9v^2}{72q}$ $\Pi=\frac{\frac{q}{6}+(q+v)^2}{4q}$	$\max_k \frac{1}{12}(k+q+v)-\frac{k^2}{2}$ $k=\frac{1}{12}$ $\pi^C=\frac{1}{288}(1+24q+24v)$ $\Pi=\frac{\frac{q}{12}+(q+v)^2}{4q}$
M_1^{MC}	$\max_k(\frac{2kq+(q+v)^2}{8q}-\frac{k^2}{2})$ $k=\frac{1}{4}$ $\pi^A=\frac{q+4q^2+8qv+4v^2}{32q}$ $\Pi=\frac{\frac{q}{4}+(q+v)^2}{4q}$	$\max_k(\frac{k}{4}-\frac{k^2}{2})$ $k=\frac{1}{4}$ $\pi^C=\frac{1}{32}$ $\Pi=\frac{\frac{q}{4}+(q+v)^2}{4q}$
M_2	$\mathbf{\max_k(\frac{(q+v)^2}{8q}+\frac{(f-k)^2}{4k}-\frac{k^2}{2})}$ These are objective functions under M_2 structure *	$\mathbf{\max_k(\frac{(f-k)^2}{4k}-\frac{k^2}{2})}$

***: Unfortunately the maximization problem is not well defined. I couldn't find the problem in my previous calculation.**

Proposition 1: A complete patent pool with marginal contribution profit sharing rule leads to a higher investment level in the incremental technology than the pool with equal split profit sharing rule.

Proof: $\frac{1}{4}>\frac{1}{6}$; $\frac{1}{4}>\frac{1}{12}$

Proposition 2: Under profit equal split sharing rule, outside innovator invests less than the pool member in inventing the incremental technology

Proof: $\frac{1}{12}<\frac{1}{6}$

II.1. 4. Welfare comparison

Plug optimal k into expressions of R_i, r and θ, i = 2, 3, we can calculate the licensee's surplus (consumer surplus) and thus analyze the effect on welfare.

Under M_1^{ES}, $k = \frac{1}{6}$ if A owns IT:

If $v < q$,

$$\int_{\frac{1}{2}-\frac{v}{q}}^{\frac{1}{2}} (v + q\theta - \frac{q+v}{2})\, d\theta + \int_{\frac{1}{2}}^{1} (v + (q + \frac{1}{6})\theta - \frac{q+v}{2} - \frac{1}{12})\, d\theta = \frac{1}{48} + \frac{q}{8} + \frac{v}{4}$$

If $v \geq q$,

$$\int_{0}^{\frac{1}{2}} (v + q\theta - \frac{q+v}{2})\, d\theta + \int_{\frac{1}{2}}^{1} (v + (q + \frac{1}{6})\theta - \frac{q+v}{2} - \frac{1}{12})\, d\theta = \frac{1}{48} + \frac{v}{2}$$

Under M_1^{ES}, $k = \frac{1}{12}$ if C owns IT:

If $v < q$,

$$\int_{\frac{1}{2}-\frac{v}{q}}^{\frac{1}{2}} (v + q\theta - \frac{q+v}{2})\, d\theta + \int_{\frac{1}{2}}^{1} (\frac{1}{24}(-1 + 12v + 2\theta + 12q(-1 + 2\theta)))\, d\theta = \frac{1}{96} + \frac{q}{8} + \frac{v}{4}$$

If $v \geq q$,

$$\int_{0}^{\frac{1}{2}} (v + q\theta - \frac{q+v}{2})\, d\theta + \int_{\frac{1}{2}}^{1} (\frac{1}{24}(-1 + 12v + 2\theta + 12q(-1 + 2\theta)))\, d\theta = \frac{1}{96} + \frac{v}{2}$$

Under M_1^{MC}, $k = \frac{1}{4}$:

If $v < q$,

$$\int_{\frac{1}{2}-\frac{v}{q}}^{\frac{1}{2}} (v + q\theta - \frac{q+v}{2})\, d\theta + \int_{\frac{1}{2}}^{1} (\frac{1}{8}(-1 + 4v + 2\theta + q(-4 + 8\theta)))\, d\theta = \frac{1}{32} + \frac{q}{8} + \frac{v}{4}$$

If $v \geq q$,

$$\int_{0}^{\frac{1}{2}} (v + q\theta - \frac{q+v}{2})\, d\theta + \int_{\frac{1}{2}}^{1} (\frac{1}{8}(-1 + 4v + 2\theta + q(-4 + 8\theta)))\, d\theta = \frac{1}{32} + \frac{v}{2}$$

Total welfare comparison:

$v \geq q$

Payoffs are summarized and listed in the following table:

	A invests in IT	C invests in IT
M_1^{ES}		
$v < q$	$TW = \frac{q+6q^2+12qv+4v^2}{16q}$	$TW = \frac{1}{32}(1 + 12q + 24v + \frac{8v^2}{q})$
$v \geq q$	$TW = \frac{1}{16} + \frac{q}{4} + v + \frac{v^2}{4q}$	$TW = \frac{1}{32} + \frac{q}{4} + v + \frac{v^2}{4q}$
M_1^{MC}		
$v < q$	$TW = \frac{1}{32}(3 + 12q + 24v + \frac{8v^2}{q})$	
$v \geq q$	$TW = \frac{3}{32} + \frac{q}{4} + v + \frac{v^2}{4q}$	

Proposition 3: Under complete patent pool structure with an incremental technology, the marginal contribution profit sharing rule leads to higher consumer surplus and total welfare than the equal split profit sharing rule.

Proof: $\frac{3}{32} + \frac{q}{4} + v + \frac{v^2}{4q} > \frac{1}{16} + \frac{q}{4} + v + \frac{v^2}{4q}$; and $\frac{3}{32} + \frac{q}{4} + v + \frac{v^2}{4q} > \frac{1}{32} + \frac{q}{4} + v + \frac{v^2}{4q}$

II.2. Substitute technology strategy

In this case, the innovator chooses to invest in and invents a substitute technology there are also two possible products in the final market: lower quality product, L, with a performance level q and an inferior quality product, I, with a performance level $q - g$. q is exogenous and g is a choice variable to the innovator. We use Q as a quality level index, $Q = q, q - g$.

Assumptions:

1. For simplicity, we assume marginal cost to any patent holder is zero.
2. The licensees who plan to produce H product will face two types of technology market structures, M_1 and M_2. If a patent pool including T_a, T_b, and ST has been formed, we call it structure M_1. If the substitute patent does not become the member of the pool, we call it structure M_2. Under M_1, the pool sets royalty R_2 for T_a and T_b and sets royalty R for the substitute technology. Under M_2, the pool set royalty R_2 for the two basic patents and the substitute patent owner sets royalty R for the new patent. Assume that the patent pool cannot discriminate between licensees who produced L and those who produce I under M_2.
3. A licensee of type θ has a reservation value $V(\theta) = v + \theta Q$, $Q = q, q - g$.

We can write down the surplus of licensee of type θ as below:

$$\pi(\theta, L) = v + q\theta - R_2$$

$$\pi(\theta, I) = v + (q - g)\theta - R$$

So licensee of type θ will choose L if $\theta > \frac{R_2 - v}{q}$

I If $\frac{R-v}{q-g} < \theta < \frac{R_2 - v}{q}$,

and buy nothing if $\theta < \frac{R-v}{q-g}$

Under M1 structure, the pool

$$\max_{R_2,\ R} R_2\left(1 - \frac{R_2 - v}{q}\right) + R\left(\frac{R_2 - v}{q} - \frac{R - v}{q - g}\right)$$

Solutions: $R_2 \to \frac{2q^2 + gv + 2qv}{g + 3q}$, $R \to \frac{g(-q+v) + q(q+v)}{g+3q}$

Pool's total profit: $\frac{g^2 v + gq(q+v) - q(q+v)^2}{g^2 + 2gq - 3q^2}$

Under M2 structure,

the pool: $\max_{R_2}\ R_2\left(1-\frac{R_2-v}{q}\right)$

ST owner: $\max_{\ R}\ R(\frac{R_2-v}{q}-\frac{R-v}{q-g})$

Solutions: $R_2 \rightarrow \frac{q+v}{2}, R \rightarrow \frac{g(-q+v)+q(q+v)}{4q}$

Pool's profit: $\frac{(q+v)^2}{4q}$

ST owner earns: $\frac{(g(-q+v)+q(q+v))^2}{16q^2(-g+q)}$

Note that the pool's total profit is strictly lower with ST in it. I.s.

$$\frac{g^2v+gq(q+v)-q(q+v)^2}{g^2+2gq-3q^2} < \frac{(q+v)^2}{4q}$$

Thus, we can rule out the M_1 structure in our analysis with substitute technology. And the profit sharing rule within the pool is not an issue.

Payoffs are summarized and list in the following table:

	A owns both T_a and ST	C owns ST
M_1	$\pi_A = \frac{g^3v+g^2(6q-v)v-4q^2(q+v)^2+gq(4q^2+qv-3v^2)}{2(g-q)(g+3q)^2}$ $\pi_B = \frac{(g+q+v)(2q^2+gv+2qv)}{2(g+3q)^2}$	$\pi_A = \frac{(g+q+v)(2q^2+gv+2qv)}{2(g+3q)^2}$ $\pi_B = \frac{(g+q+v)(2q^2+gv+2qv)}{2(g+3q)^2}$ $\pi_C = \frac{(g(q-v)+q(q+v))^2}{(q-g)(g+3q)^2}$
M_2	$\pi_A = \frac{(g(-q+v)+q(q+v))^2}{16q^2(-g+q)} + \frac{(q+v)^2}{8q}$ $\pi_B = \frac{(q+v)^2}{8q}$	$\pi_A = \frac{(q+v)^2}{8q}$ $\pi_B = \frac{(q+v)^2}{8q}$ $\pi_C = \frac{(g(-q+v)+q(q+v))^2}{16q^2(-g+q)}$

Investment decision:

Work in progress.

III. A Benchmark Model – No patent pools

III.1. Incremental technology strategy

Firm A: $\max_{R_a}\ R_a(1-\frac{R_a+R_b-v}{q})$

Firm B: $\max_{R_b}\ R_b(1-\frac{R_a+R_b-v}{q})$

Firm C or A: $\max_{r}\ r(1-\frac{r+f}{k})$

Solution: $r \to \frac{k-f}{2}$, Ra $\to \frac{q+v}{3}$, Rb $\to \frac{q+v}{3}$

If A owns IT: A's profit = $\frac{(q+v)^2}{9q}+\frac{(f-k)^2}{4k}$, B's profit = $\frac{(q+v)^2}{9q}$

If C owns IT: A or B's profit = $\frac{(q+v)^2}{9q}$; C's profit = $\frac{(f-k)^2}{4k}$

III.2. Substitute technology strategy

III.2.1 C owns ST:

Firm A: $\max_{R_a}\ R_a(1-\frac{R_a+R_b-v}{q})$

Firm B: $\max_{R_b}\ R_b(1-\frac{R_a+R_b-v}{q})$

Firm C: $\max_{R} R(\frac{\mathbf{Ra+Rb}-\boldsymbol{v}}{\boldsymbol{q}}-\frac{\boldsymbol{R-v}}{\boldsymbol{q-g}})$

Solution: $R \to \frac{g(-2q+v)+2q(q+v)}{6q}$, Ra $\to \frac{q+v}{3}$, Rb $\to \frac{q+v}{3}$

Profit for A and B: $\frac{(q+v)^2}{9q}$

Profit for firm C: $\frac{(g(v-2q)+2q(q+v))^2}{36(q-g)q^2}$

III.2.2 A owns ST:

Firm A: $\max_{R,\ Ra}\ R_a(1-\frac{R_a+R_b-v}{q})+R(\frac{\mathrm{Ra+Rb}-v}{q}-\frac{R-v}{q-g})$

Firm B: $\max_{R_b}\ R_b(1-\frac{R_a+R_b-v}{q})$

Solution: $R \to \frac{g(-2q+v)+2q(q+v)}{g+5q}$, Ra $\to \frac{g(-q+v)+3q(q+v)}{g+5q}$, Rb $\to \frac{q(g+q+v)}{g+5q}$

Firm A profit:

$$\frac{-g^2q(q-6v)+g^3(-q+v)-7q^2(q+v)^2+gq(9q^2+7qv-2v^2)}{(g-q)(g+5q)^2}$$

Firm C profit: $\frac{q(g+q+v)^2}{(g+5q)^2}$

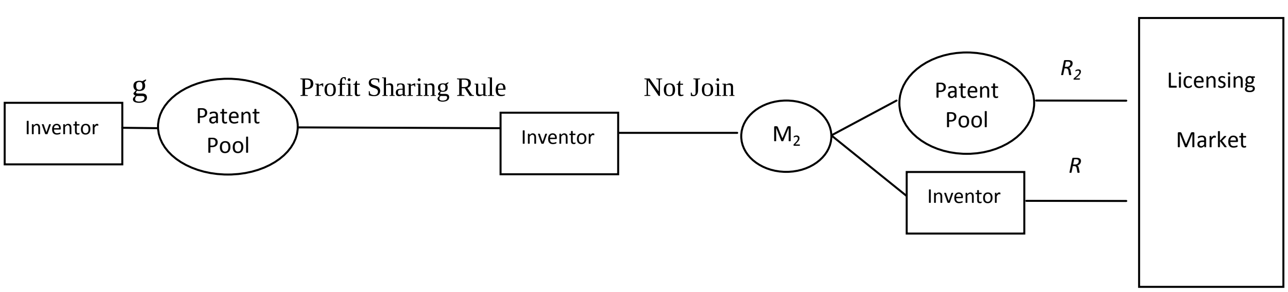
IV. Extensions of the model

IV.1. Revise the stages of the game and build a bargaining model in deciding the profit sharing rules.

In our previous analysis, the profit sharing rule is solely determined by the existing patent pool. In reality, it is more likely that the potential new member of the patent pool might negotiate the profit sharing rules with the pool before making the decision to join or not. In this section, we add a bargaining model to the second stage of the game and analyze how it will reshape the game.

IV. 2. Antitrust policy framework and its influence.

In section II.2, we assume that the patent pool can include both T_a, T_b, and ST in the pool even though ST is a substitute technology. In reality, forming such a patent pool might have been rejected by the department of Justice due to the antitrust concern. So far, the Department of Justice has displayed a keen understanding of the need for those holding complementary rights to coordinate in the licensing of those rights, but the Federal Trade Commission has exhibited less restraint, and arguably is making it more difficult for firms to engage in cross licenses, to offer package licenses, or to form procompetitive patent pools. In this section, let's consider the case where ST is not allowed to join the patent pool. Then the lower half of the game tree will be revised as the following:



V. Concluding discussion

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